# A Robust Framework for Benchmarking Seismic Performance of Modern New Zealand Code-Conforming Buildings

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## 1. Background and Objective

This poster presents an overview of the project defined to develop a robust framework for benchmarking the seismic performance of modern New Zealand code-conforming buildings including conventional and low-damage concrete and steel structures. The immediate need for this project has been seen through UC Quake Centre's engagement with engineering practitioners. This framework follows the methodology introduced by Pacific Earthquake Engineering Research (PEER) centre for performance-based earthquake engineering. PEER's framework was primary developed to improve the decision-making procedures regarding the seismic performance of the buildings using some measurable decision variables. It provides a comprehensive understanding of risk exposures related to structural and non-structural components and building contents and facilitate decision making for territorial authorities, property owners, commercial tenants, engineers, and contractors. Figure 1 illustrates the fundamental steps considered in PEER's framework.

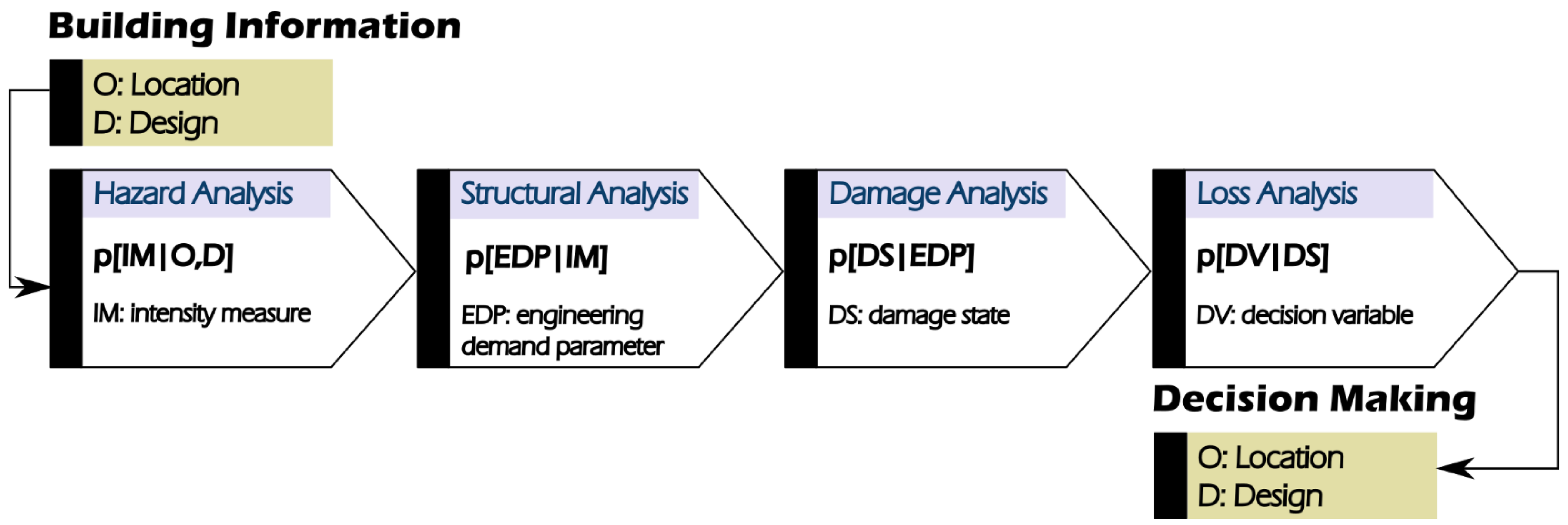


**Figure 1: PEER's framework for performance-based earthquake engineering.**

Benchmarking the seismic performance of code-conforming designs will be meaningful only if a broad range of design and detailing configurations are considered. In this matter, a design space including numerous archetype designs is developed to consider various structural configuration issues and seismic behavioural effects. This design space is, consequently, assessed through the PEER's framework.

In this project, the benchmarking framework has been initially developed for reinforced concrete (RC) moment frame buildings with the intention to be simply extended for other building types. The results of using PEER's framework for a case study building is presented in this poster.

## 2. Case Study Building

The archetype design investigated herein (known in New Zealand as Redbook Building) is a building with ductile reinforced concrete moment frames as a seismic-force-resisting system (CCANZ 2008). It was designed and detailed as per New Zealand Structural Design Actions Standard (NZS1170.5 2004) and Concrete Structures Standard (NZS3101:Part1 2006). The building layout is illustrated in Figure 2.

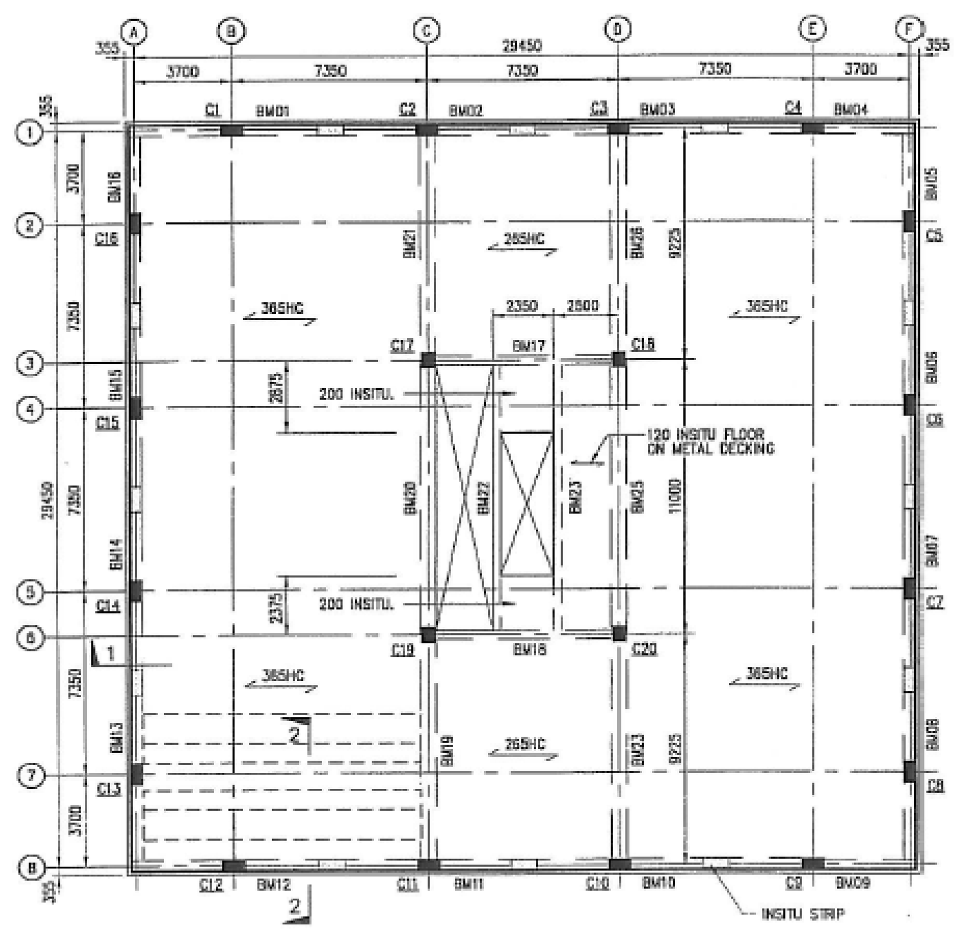

**Figure 2: The layout of Redbook building.**

## 3. Structural Model

A concentrated plasticity model capturing primary cyclic deteriorations modes has been used in this study. The deterioration modes considered are illustrated in Figure 3.

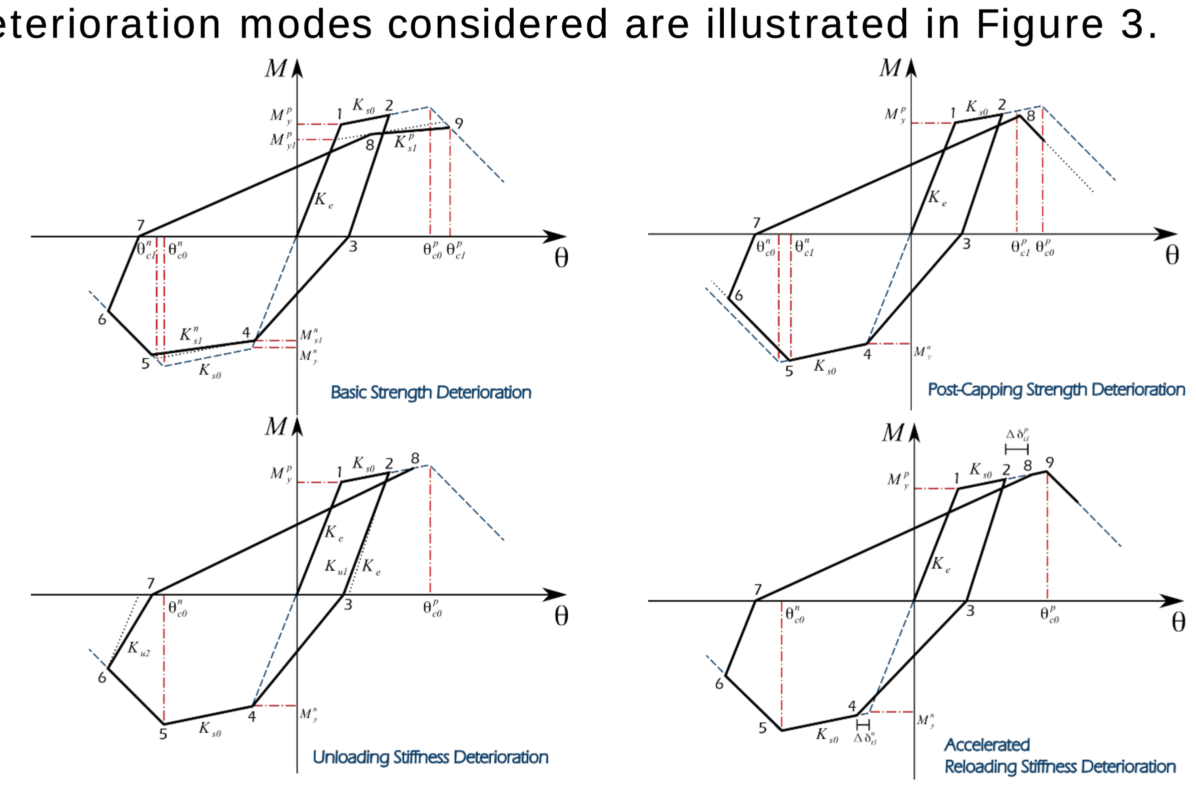


**Figure 3: Cyclic deterioration modes of element hinges.**

## 4. Seismic Performance

The summary statistics of the hazard and structural analysis performed provide rigorous means to achieve the foremost objectives of seismic performance benchmarking including:

- Quantification of building response at various hazard levels and assessment of design assumptions and detailing configurations.
- Development of hazard curves for engineering demand parameters.
- Evaluation of collapse fragility including probability distribution of collapse, median collapse intensity, and associated dispersion.
- Computation of collapse margin ratio (CMR) defined as the ratio between the median collapse capacity and the maximum considered earthquake intensity. Collapse margin ratio is an effective measure for characterizing the collapse safety of the structure.
- Calculation of annual rate of collapse representing an effective metric for assessing collapse safety.

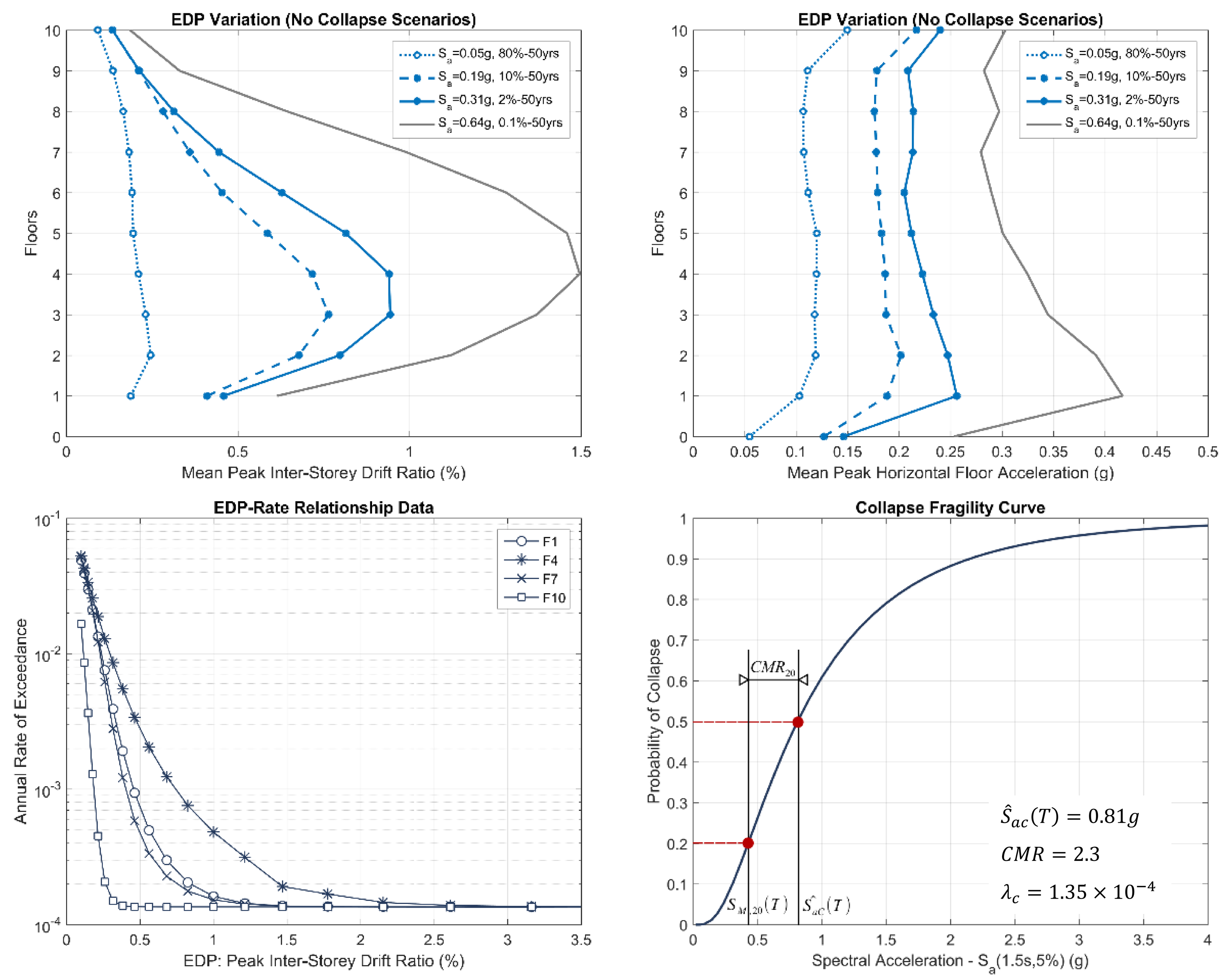


**Figure 4: Illustration of (a) mean peak inter-storey drift ratio, (b) mean peak floor acceleration, (c) hazard curves for peak inter-storey drift ratio, and (d) collapse fragility.**

## 5. Seismic Loss Assessment (OpenSLAT)

OpenSALT, an open seismic loss assessment tool, that has been developed at the University of Canterbury, has been used in this study to perform seismic loss assessment.

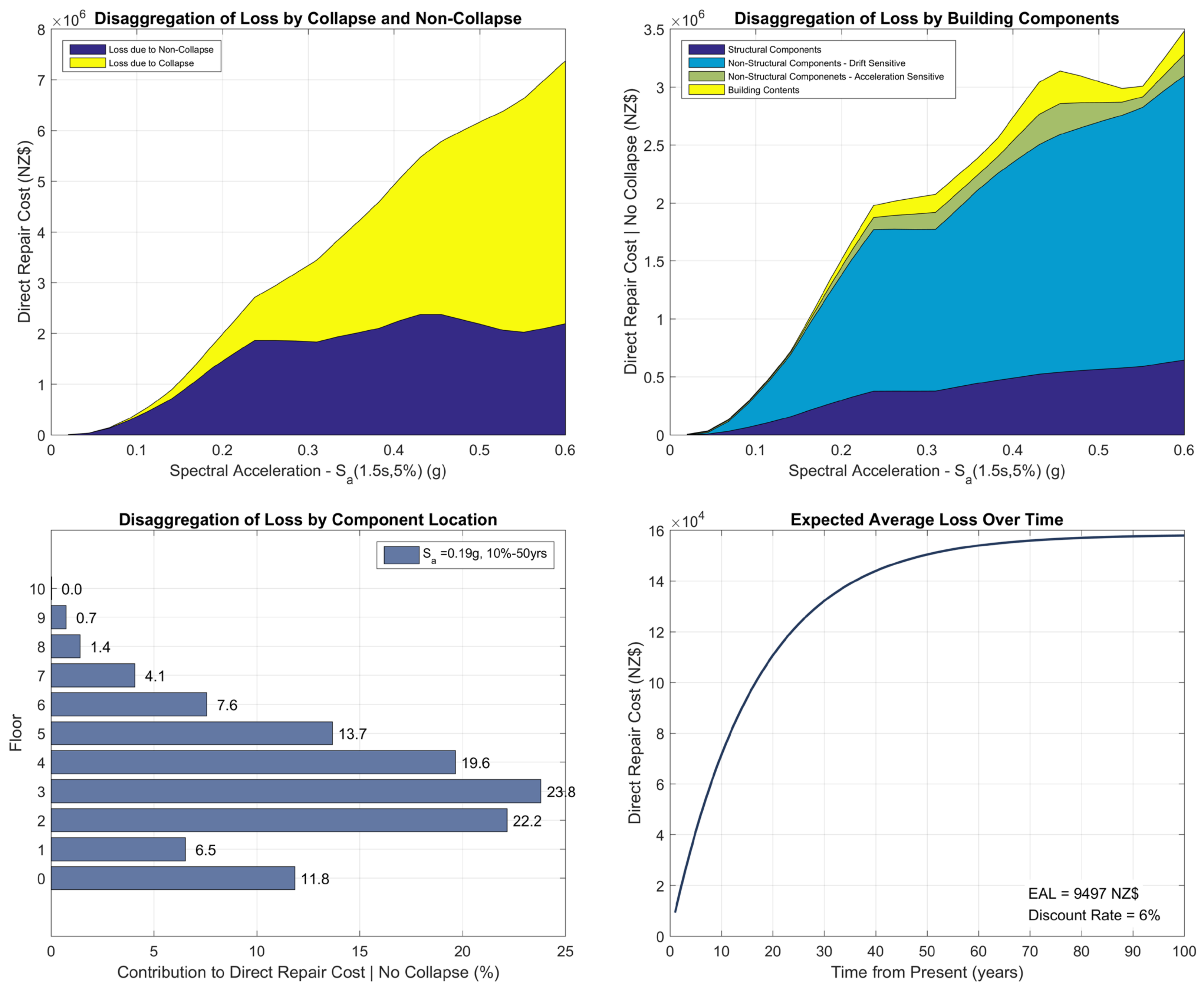


**Figure 5: Illustration of (a) loss-intensity relationship, (b-c) loss disaggregation, and (d) expected loss over time.**

## 6. Direct Economic Loss

An appropriate benchmarking of seismic performance of a building requires a quantifiable relationship between the ground motion intensity (i.e. seismic hazard) and the expected economic loss in a building. In this matter, quantification of the following losses are insightful for decision making process:

- Loss-intensity relationship for entire structure considering global structural collapse and non-collapse cases.
- Disaggregation of non-collapse loss by building components.
- Disaggregation of non-collapse loss by location of building components.
- Net present value of the expected loss over time.